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Alpha Town Flood Mitigation Study
Final Report – Volume 1
Barcaldine Regional Council

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Contents

1. Introduction

1.1 General

Connell Wagner was commissioned in August 2005 by Barcaldine Regional Council ("BRC") to undertake a detailed assessment of Alpha Creek flooding in the vicinity of the town of Alpha and to determine a range of mitigation options aimed at reducing the impact of flood events upon the town. The town of Alpha lies on the Capricorn Highway, approximately 170 km west of Emerald and 54 km east of Jericho as shown on Figure 1. The town is also located on the main Central Railway to Longreach.

Alpha Creek forms part of the upper catchment of the Burdekin River system. The Alpha Creek system has a catchment area of approximately 2630 km^2 to Alpha. Approximately 15km downstream of Alpha, Native Companion Creek joins Alpha Creek. The total catchment area at this confluence is approximately 4170 km^2.

The town of Alpha has been affected by several significant flood events over the past sixty years. The most severe event was that of April 1990, with an estimated maximum flood height of 10.26 m recorded at the town gauge on the upstream side of the main railway bridge. This resulted in inundation of a large proportion of the town and evacuation of seventy percent of the population. Several other major events have occurred including the November 1950, February 1997 and February 2003. Neither the 1997 nor 2003 event entered the town.

1.2 Study scope

Barcaldine Regional Council has received funding through the Federal and State Governments under the Natural Disaster Mitigation Program ("NDMP") to evaluate the current floodplain situation; identify the potential of continuing flood losses; and recommend a program of short and long-term measures that will alleviate the impacts of flooding in Alpha.

The NDMP has been initiated by the Commonwealth Government. In the past similar types of programs have just reacted to disaster while the NDMP seeks to anticipate and mitigate disaster. The NDMP provides funding for measures such as risk management studies and mitigation works to assist communities better to withstand the effects of natural disaster. The Queensland Government, through the Department of Emergency Services ("DES") is responsible for the administration of the NDMP in Queensland. Barcaldine Regional Council has formulated the Alpha Flood Mitigation Working Group (the Study Group) which included representatives from the community, Council, Department of Main Roads ("DMR"), Queensland Rail ("QR"), Queensland Police Service ("QPS"), State Emergency Services ("SES") and the Department of Natural Resources and Water ("NRW").

Study scope includes the development of a detailed 2-dimensional (2d) hydraulic model of Alpha Creek and its floodplain to the confluence with Native Companion Creek. The model has been calibrated against three historical flood events – April 1990, February 1997 and February 2003. The April 1990 event inundated the town while the other two events did not enter the town area. Using the calibrated model the impacts of the existing infrastructure, in particular the Capricorn Highway and Central Railway, on flooding have been quantified. Mitigation works and drainage improvements have been determined and considered in terms of physical, economic and social benefit for the community. Consequently the Study not only entails hydrologic and hydraulic investigations, economic and cost/benefit analysis but also community consultation. Consultation with the Study Working Group and local residents has been undertaken throughout the project with input and feedback sought at key stages of the project.

2. Background

2.1 General

Figure 2 presents the Alpha Town layout. Key features in the vicinity of the Alpha township include:

- Alpha Creek, flowing south to north, which winds around the eastern side of the town
- The north-facing main street (Shakespeare Street) with two hotels and several shops which serve the local community and tourists using the Capricorn Highway
- The town hall in the middle of the town
- Council Offices on the western side of town

Alpha has approximately 150 buildings including Shire offices, a public hall, two hotels, several shops and a number of residences some dating back 100 years. Most of the residences are partially raised. The current population of Alpha is 360 (pers comm).

The Central Railway line runs east-west through Alpha and crosses Alpha Creek. The Capricorn Highway approaches the town from the south-west then swings north through the town before following the railway line west. Alpha Creek flows from the south around the town on the eastern side then flows northwards.

2.2 Flooding mechanisms

From discussion with the community and Study Group regarding their recollections of the April 1990 flood, and from results of the hydraulic modelling, a thorough understanding of the behaviour of flooding in and around Alpha has been obtained.

The town of Alpha lies largely on the natural left overbank of Alpha Creek. Flood waters initially break out on the western bank of Alpha Creek in the vicinity of Scott Street and also along the Capricorn Highway into town. At the same time floodwaters break out on the eastern bank of the creek.

Flood waters enter town from breakouts on the western bank, directing water through the majority of the lower section of the town area. There is a natural flow path between Moore and Swinburne Streets which has been kept mostly clear of development and this conveys a substantial portion of flood waters.

A levee was constructed in 1983 on the western bank between the hospital and the Capricorn Highway. However, during the April 1990 event it was breached and has never been reinstated. The peak depth of flood waters within Alpha during the 1990 flood event was approximately 2.5m.

The Alpha town layout is shown in Figure 2. General flow patterns during the progression of a significant flood event are shown on Figure 3.

3. Data collection and review

An extensive amount of data was collected during the early stages of the project. This included material held by Barcaldine Regional Council, the Bureau of Meteorology, the Department of Main Roads, Queensland Rail, the Department of Natural Resources and Water, George Bourne & Associates and the local residents of Alpha. The contribution of all organisations and individuals is gratefully acknowledged.

The data obtained was reviewed and provided vital input to the Flood Study. Details of the data collected are summarised below.

In addition to the data listed below, the Study Team carried out a thorough site inspection of the Alpha township, Alpha Creek and the surrounding area. This provided first-hand knowledge of a number of items including:

- Key features and local flow paths through town
- Examination and assessment of breakout flow paths from Alpha Creek and the Jump-up location
- Review of the type and density of vegetation in Alpha Creek and on the floodplain
- Examination of road and rail links and state of existing cross-drainage structures

3.1 Previous studies

The following relevant reports were provided for use in the Flood Mitigation Study:

- Western Queensland Towns Flood Study – Volume 1 (Scott & Furphy, January 1991)
- Western Queensland Towns Flood Study – Volume 2 (Scott & Furphy, January 1991)

3.2 Historical flood event information

Alpha has experienced a number of large events in recent times. The most significant event occurred in April 1990 with substantial inundation and evacuation of the town. Three other large events took place in November 1950, February 1997 and February 2003 with no flood waters entering the town but inundation of the surrounding land occurring.

A range of information regarding historical events was collected including:

- Oblique photography (Western Queensland Towns Flood Study, Scott & Furphy Report, 1991) from aircraft during the 1990 event
- Photographs of 1997 and 1999 flood events showing inundation throughout Alpha
- Surveyed flood level marks on a number of houses and buildings throughout Alpha
- Records of local rainfall readings collected by local residents
- Advice from local residents and the Study Working Group regarding upstream breakout paths, and flood depths, velocities and flowpaths of flood waters through Alpha

3.3 Aerial photography

Aerial photography of the town of Alpha was provided by Barcaldine Regional Council. It was flown in August 2000 at a height of 1875m.

3.4 Survey data

A digital terrain model was compiled from the aerial photography taken in August 2000. This formed the basis of the survey around Alpha town.

Additional cross-sections were surveyed by Hoffman Surveyors. Two cross-section were obtained upstream and three downstream of Alpha. These were used to provide details of the creek channel and overbanks outside of Alpha town.

3.5 Cross-drainage structure details

To enable an accurate hydraulic model to be constructed, it was important to obtain accurate details of hydraulic structures, such as culverts and bridges. The following drawings and plans were sourced:

- Capricorn Highway design drawings (1970-86) (DMR)
- MR Plan No. 103332
- MR Plan No. 167381
- MR Plan No. 208413
- MR Plan No. 208782
- MR Plan No. 104076
- GBA Plan No. 06-015
- Emerald to Longreach Railway design drawings (circa 1964) (QR)

3.6 Stream Gauge, Rainfall data and URBS Model

Stream gauge records, daily rainfall and pluviograph data for various nearby gauging stations were sourced from the Bureau of Meteorology (BoM).

An URBS hydrologic model for the catchment of Alpha Creek to the confluence with Native Companion Creek was also sourced from the BoM. This was used to assist in the joint calibration process.

3.7 Environmental data

Environmental data was obtained from several sources. These included:

- Wildnet – Environmental Protection Agency (EPA)
- Regional Ecosystems mapping (EPA)
- Cultural Heritage Register (EPA)
- Native Title Register (EPA)
- Barcaldine Regional Council

4. Consultation activities

Consultation is a key element of this project, with local residents and Study Working Group members providing valuable input to all stages of the project. A range of activities has been undertaken as detailed below.

4.1 Study newsletters

Newsletters were utilised as a method of conveying study information to members of the community and interested stakeholders. They were designed to inform the community of the study and its objectives and ensure the community is updated regarding the study progress.

Three newsletters were sent to residents and interested stakeholders throughout the project. Copies of these are included in Appendix A.

4.2 Public meetings

In addition to the newsletters, public meetings were held as another forum for keeping the community informed. The meetings also served as a mechanism for the community to provide input into the study. Two public meetings were conducted, the first on 18 September 2005 and the second on 23 January 2007.

Valuable information was obtained from local residents and recorded by way of survey forms, completed by residents individually or by a member of the Study Team. A copy of the survey forms can be found in Appendix B.

4.3 Study working group workshops

The Study Working Group consists of the following parties:

- Community representatives
- Barcaldine Regional Council
- Department of Main Roads
- Queensland Rail
- Queensland Police
- State Emergency Services
- Department of Natural Resources and Mines

Two workshops with the Study Team (Connell Wagner) and the Study Working Group were undertaken. The first workshop was originally to be undertaken prior to the first public meeting but it was decided to combine the meetings to provide a more efficient method of providing and gathering information. The group were briefed on the proposed project methodology and advised the study team of the issues and mitigation options, thought to be relevant to the project.

The second Study Group meeting coincided with the second Public Meeting.

4.4 Public display

A copy of the Draft Report and associated drawings were put on public display and available for local residents to examine and provide feedback on forms provided.

4.5 Key issues

A number of issues were identified during the initial consultation processes with Council, the community and stakeholders. These have been addressed in this study and include:

- The impact of the Capricorn Highway on flooding
- The impact of the Central Railway on flooding
- Mitigation measures to reduce flooding in the town
- The impact that mitigation measures may have on surrounding properties
- The extent to which commercial activities and residences are at risk from future flooding and the impacts/benefits of structural and non-structural mitigation works

Suggestions on measures to mitigate the effects of floods, provided by Council and residents during consultation activities, included:

- Removing the Capricorn Highway and/or the Central Railway embankment and structures
- Replacing the existing rail bridge to provide additional waterway area
- Constructing new levees
- Channel maintenance
- Constructing a dedicated floodway

Where possible, the suggestions and issues raised have been addressed in the study outputs. The community consultation process as a whole should be considered a success.

5. Hydrologic model development

5.1 URBS modelling package

The hydrologic modelling of the Alpha Creek and Native Companion Creek catchments has been carried out using the URBS model (Version 3.9). The URBS program is a runoff-routing program developed by Brisbane City Council and the Department of Primary Industries (Water Resources). Two different routing models are available to model the sub-catchment and channel storage routing behaviour. These are the URBS Basic and Split models. The Split model has been used for hydrological modelling of the Alpha Creek and native Companion Creek catchments to provide compatibility with the BoM URBS models.

In the Split model, rainfall on the sub-areas is firstly routed to the creek channel and then along the creek channel. The inflow from the sub-catchment into the channel is assumed to occur at the centroid of the sub-catchment with the lag of the sub-catchment storage assumed to be proportional to the square root of the sub-catchment area. The catchment routing parameter of the Split model can be optionally modified to include the effect of catchment slope on the catchment response.

The time it takes for the flow to travel from the sub-catchment perimeter to the centroid can be modified to allow for the effects of urbanisation or forestation. The urbanisation/forestation factors are only applied to the sub-catchment routing component with channel flows unaffected by local sub-catchment urbanisation or forestation. This model is therefore suitable for representing large creeks or rivers where the main channel hydraulic properties are largely unaffected by the extent of catchment urbanisation or forestation.

The URBS modelling package is used by the BoM for its flood forecasting/warning models and therefore was the ideal choice for the Alpha Creek and Native Companion Creek catchments. The resulting URBS model will be provided to the BoM. Advice was sought from the BoM during the development of the model to ensure that the model remained compatible with the BoM models. Accordingly, the optional parameters of channel slope, catchment slope, urbanisation and forestation were not used and the mandatory parameters of catchment area and stream length were adopted.

5.2 Model development

The URBS model of Alpha Creek and Native Companion Creek catchments consists of 54 sub-catchments as shown in Figure 4. The catchment data, including sub-catchment boundaries and routing, were sourced from the URBS model of Alpha Creek and Native Companion Creek catchments developed by Mr Terry Malone, Senior Engineer Hydrology and Flood Warning of the BoM. Rigorous checks were made using the available 1:250,000 topographic maps to confirm the accuracy of the sub-catchment definition and routing scheme of the source model. The catchment data defined by BoM was manipulated in order to produce flow hydrographs at boundary locations of the hydraulic model and at various point source locations corresponding to hydrologic sub-catchment boundaries within the MIKE 21 model.

Discussions were held with Mr Terry Malone, Senior Engineer Hydrology and Flood Warning (BoM), regarding appropriate model parameters for catchments in Western Queensland. He recommended that the parameters of m and β should remain constant but the α parameter will need to be adjusted during the joint calibration phase. The rainfall loss parameters (initial and proportional) were also adjusted to assist in the calibration process.

Table 5-1 presents the sub-catchment details as used in the URBS model.

Table 5-1 URBS sub-catchment parameters

Sub-Catchment	Area (km^2)	Sub-Catchment	Area (km^2)
1	16.9	28	37.4
2	9.1	29	60.8
3	60.2	30	85.3
4	37.8	31	123.2
5	62.7	32	62.6
6	83.8	33	60.4
7	129.7	34	92.5
8	48.9	35	137.1
9	47.8	36	127.9
10	97.7	37	137.9
11	17.6	38	60.7
12	49.0	39	86.2
13	102.2	40	165.9
14	129.6	41	105.9
15	112.3	42	149.4
16	53.7	43	70.7
17	62.5	44	52.5
18	48.5	45	69.5
19	143.7	46	102.6
20	91.4	47	35.7
21	87.1	48	11.4
22	13.1	49	171.7
23	127.8	50	26.7
24	66.4	51	68.8
25	114.1	52	30.1
26	22.2	53	97.2
27	92.4	54	7.6
Total Catchment Area		4165.7 km^2	

6. Hydraulic model development

6.1 MIKE 21 modelling package

On the Alpha Creek floodplain, floodwaters break out at many locations from the creek during flood events. This wide spread flow with multiple breakouts and complex flow paths is best represented by a two-dimensional hydraulic model. Therefore modelling for this investigation was undertaken using the Danish Hydraulic Institute's ("DHI") MIKE 21 package. MIKE 21 is a comprehensive modelling system for two-dimensional free surface flows where stratification can be neglected. MIKE 21 simulates the water level variations and flows in response to a variety of forcing functions in floodplains, lakes, estuaries, bays and coastal areas. The water levels and flows are resolved on a rectangular grid covering the area of interest when provided with the bathymetry (topography), bed resistance coefficients, wind field, hydrographic boundary conditions etc.

MIKE 21 solves the vertically integrated equations of continuity and conservation of momentum in two horizontal dimensions using implicit finite difference methods. The following effects are included in the equations:

- Convective and cross momentum
- Wind shear stress at the surface
- Barometric pressure gradients
- Coriolis forces
- Momentum dispersion ("eddy")
- Sources and sinks (both mass and impulse)
- Evaporation

A MIKE 21 generated model has only three calibration factors, namely bed resistance, wind friction and momentum dispersion. Using these factors alone, calibration of a model is normally quite easy. In practice, the calibration of a model depends far more on the accuracy of the data, eg topography and boundary conditions.

The MIKE 21 data requirements for this project included the following:

- Basic Model Parameters
  - Model grid size and extent
  - Time step and length of simulation
  - Type of output required and its frequency

- Topography

- Calibration Factors
  - Bed resistance
  - Momentum dispersion coefficients

- Initial Conditions
  - Water surface level
  - Flux densities in x and y directions

- Boundary Conditions
  - Water levels or flow magnitude
  - Flow direction

The data used for each of the above parameters are detailed in the following section.

6.2 Alpha Creek model development

The first step in the development of the MIKE 21 model of Alpha Creek was to use the terrain modelling package '12D' to review the DTM and prepare the data in a format suitable for input into the MIKE 21 hydraulic modelling package. The additional surveyed cross-sections up and downstream of the DTM were included to interpolate the terrain beyond the extent of the provided DTM. The extent of the terrain is shown in Figure 5. The terrain data was rotated 22.5 degrees anti-clockwise to orientate major structures (road and rail bridges over Alpha Creek) perpendicular to the MIKE 21 grid orientation.

A 10 metre grid spacing was adopted – this gave large, but acceptable file sizes and a good level of detail in the hydraulic model, particularly in the vicinity of Alpha and the Alpha Creek breakout points. The topography used in the model is presented in Figure 5. To satisfy model stability criteria, a timestep of 3 to 5 seconds was adopted.

A roughness map for the model extent was prepared using information gained from the site inspection, photographs of the creek and the aerial photograph. Figure 6 shows the roughness values applied to the model.

The main channel consists of mainly a sandy/gravelly/rocky base, with riparian vegetation and trees along the banks, generally giving way to grasslands. The grasslands consist of sparse trees, with low sparse shrubs on the ground. To the south of the town is grasslands with a higher density of vegetation. Other areas include cleared grasslands, road reserves and habitable areas within town. The roughness values presented in Table 6-1 were used to represent each of these distinct areas.

Table 6-1 MIKE 21 Manning's Roughness Values

Location	Manning's Roughness Values 'n'
Alpha Creek bed	0.05
Channel with Vegetated Riparian Band	0.08
Grassland with sparse trees and shrubs	0.06
Grassland with thicker vegetation	0.08
Cleared Grassland	0.08
Road Reserves	0.04
Habitable areas	0.08

The Manning's 'n' value of 0.08, used for habitable areas, was adopted to account for the impedance to flow caused by buildings, fences and other obstructions.

The eddy viscosity for the model extent was generally set at a (velocity base) value of $0.25m^2/s$. Wind shear stress was neglected for all cases. The boundary conditions for the MIKE 21 model consisted of a flux density (ie inflow hydrograph) across the upstream boundary of the model and a fixed tailwater level of RL 337.5mAHD along the downstream boundary. Testing of this downstream boundary was carried out to make sure it was not influencing upstream model results.

7. Calibration of models

7.1 Selection of calibration events

The selection of calibration events for a joint calibration process requires specific data for each event including:

- Rainfall Depths (eg daily rainfall data)
- Rainfall Distribution (eg pluviograph data)
- Recorded Flood Levels for the event

Rainfall and pluviograph data was sourced from the BoM and NRM for available rainfall stations close to Alpha.

Three events where chosen to undertake the calibration. These events were the April 1990, February 1997 and February 2003. Of these three events only the April 1990 event entered the town, and hence recorded flood levels in Alpha were only available for this event. Levels at the stream gauge in Alpha Creek were available for all three historical flood events.

A summary of the available data is shown in Table 7-1. The locations of these stations are presented on the BoM map in Appendix E.

Table 7-1 Rainfall, Stream Gauge and Pluviograph Data Availability

Station Name	Station Number	Station Type	1990	1997	2003
Native Companion Creek at Violet Grove	120305a (AWRC)	Stream Gauge	✓	✓	✓
Alpha	120909 (AWRC)	Stream Gauge	✓	✓	✓
Rivington	120912 (AWRC)	Stream Gauge	✗	✓	✓
Alpha Post Office	035000	Daily Rainfall	✗	✓	✓
Blair Athol	035010	Pluviograph	✗	✗	✓
Dingo Post Office	035025	Pluviograph	✗	✗	✓
Giligulgul	035029	Pluviograph	✗	✗	✓
Rolleston Meteor St	035059	Pluviograph	✗	✗	✓
Tambo Post Office	035069	Pluviograph	✓	✓	✓
Taroom Post Office	035070	Pluviograph	✗	✗	✓
Rewan Station	035090	Pluviograph	✗	✗	✓
Emerald DPI Field Station	035147	Pluviograph	✓	✗	✓
Brigalow Research Stn	035149	Pluviograph	✗	✗	✓

Station Name	Station Number	Station Type	1990	1997	2003
Durrandella	035165	Daily Rainfall	✓	✗	✗
Alpha	035229	River Height	✓	✓	✓
Rivington	035236	Daily Rainfall	✗	✓	✓
Coovin	035267	Daily Rainfall	✓	✗	✗

(Note: ✓ = data available ✗ = data unavailable or incomplete)

The April 1990 event is the most recent flood event to enter the town. It is also the highest flood event on record with an estimated return period of 200 years (Scott and Furphy, 1991). As a result this event was selected as the base event for calibration of the hydrologic and hydraulic models.

Following the event, flood and debris marks were surveyed. Levels recorded in town were in the order of 351.5m AHD, relating to depths of up to 2.5m. According to Scott and Furphy, the town flood gauge was overtopped at 9.0m gauge height. The flood height was later determined by the survey of the flood marks (George Bourne and Associates) to be 10.26m gauge height. This compares to the previous record flood of 9.93m in 1950. The flood peak was reached about 9.00am on 20th April.

The pluviograph station in Alpha was inundated during the 1990 event and the pluviograph data was destroyed. Pluviograph data from other nearby stations has therefore been adopted during the hydrologic analysis.

The February 1997 and February 2003 event were also selected for calibration purposes as they were significant flood events, however for both events flood waters did not inundate the town. Calibration against stream gauge records only was carried out.

7.2 Joint calibration exercise

Joint Calibration involved adjusting the model parameters for both the hydrologic (URBS) and hydraulic (MIKE 21) models to achieve modelled results that closely match the recorded flood heights.

Calibration of the URBS model was achieved by comparing the model results obtained using the real event information against the recorded stream gauge at Alpha using BoM's information and through flood levels recorded through the town resulting from that event. Of the three events with BoM data, only the April 1990 event flooded the town. Therefore it is the only event to have recorded flood levels within the town area. However stream gauge data is available in Alpha Creek for the 1997 and 2003 events.

Calibration of the URBS model is generally undertaken by varying model parameters including the rainfall loss parameters. The rainfall loss parameters were adjusted such that a good match was achieved between the modelled levels and the recorded flood levels at the weir. Table 7-2 shows the loss parameters adopted for the relevant storm events. Advice from the BoM indicated that it is not unusual to use different loss parameters on the same URBS mode under different storm events, particularly when the sizes of the storms vary substantially.

Table 7-2 Table of URBS Rainfall Loss Parameters

Event	Initial Loss (mm)	Proportional Runoff (%)
1990	80	0.65
1997	80	0.3
2003	80	0.3

The runoff values in were adopted following consultation with BoM. While the proportional runoff fraction may appear low, it is not uncommon to use values of this order in western catchments, such as the Alpha Creek catchment. The higher proportional runoff value for the 1990 event is due to the fact that it was a large storm event.

With the URBS model calibrated, the hydrograph at Alpha was extracted and used as the inflow for the MIKE 21 model. Flood levels resulting from the MIKE 21 model were then compared with the recorded values for each event. Calibration limits for flood heights where no official stream gauge data exists are generally ± 200 to 300mm.

During the 1990 flood event there was a levee on the upstream side of the Capricorn Highway, near the hospital, which was breached and collapsed during the flood event. As it is not possible to represent changing topography in the MIKE 21 hydraulic model, two model runs have been carried out – with the full levee in place and with the breached levee in place. The results showed an insignificant difference in peak water levels and the animations of the flood event showed, at most, a half hour delay of flooding in town due to the levee being in place. However, according to Scott and Furphy this time allowed evacuation of the town centre.

Figure 7a and Figure 7b show the modelled inundation extent for the April 1990 event, both with the levee collapsed and intact. Figure 7c presents peak water depths for the April 1990 Event with the levee collapsed. Table 7-3 shows the final modelled flood levels throughout Alpha as compared to the surveyed flood levels.

Figure 8 and Figure 9 show the extent of inundation for the February 1997 and February 2003 events. The recorded and modelled flood levels at the gauge are shown in Table 7-3.

Table 7-3 Calibration Results for April 1990 Event

Flood Level Location	Surveyed Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference (mm)
Alpha Gauge	351.86	351.65	-210
5 Goldston Street	351.06	351.13	+70
4 Bryon Street	351.56	351.74	+180
10 Hooper Street	351.69	351.70	+10
5 Milton Street	351.67	351.60	-70
50 Milton Street	351.44	351.37	-70
51 Shakespeare Street	351.28	351.31	+30
47 Shakespeare Street	351.40	351.34	-60
41 Shakespeare Street	351.39	351.35	-40

Table 7-4 Calibration Results for February 1997 and February 2003 Events

Event	Alpha Gauge		Difference (mm)
	Recorded Flood Level (m AHD)	Modelled Flood Level (m AHD)	
February 1997	349.05	349.48	+430
February 2003	349.10	348.72	+380

It is believed that an acceptable calibration has been achieved. The results of the calibration exercise were presented to the Study Manager, who accepted the model calibration.

8. Evaluation of current floodplain situation

8.1 Design events and flood frequency analysis

Design flood events were developed using AR&R rainfall data and temporal patterns in the URBS hydrologic model. This produced discharges which were then routed through the MIKE 21 hydraulic model. Adopted rainfall loss parameters were based on those used for the three historical calibration events. The 100 and 50 year ARI design events used the loss parameters adopted for the 1990 calibration event whilst the losses adopted for the 1997 and 2003 events were used for events smaller than the 50 year ARI event.

In order to verify the results of the design event MIKE 21 model runs, a cross-check against historical stream gauge records was carried out. A flood frequency curve was developed using the historical flood level records for stream gauge 120909 (located at Alpha) provided by BoM. This gauge is manually read and details are only recorded when the water level rises above the three metre mark. As a result, there were only 17 recorded events for the period between 1950 and 2004. In order to conduct an accurate frequency analysis a full record, that picks up events of all sizes, is required – otherwise results of the analysis are distorted.

Using rainfall data, an attempt to determine additional data points (representing smaller flood events) was carried out. However a realistic flood frequency curve (return period versus peak water level) was not able to be derived for the Alpha gauging station.

Due to this lack of data it was proposed to use the April 1990 historical flood event as the basis for assessing mitigation options for Alpha. The 1990 event has been the largest event for 60 years. This approach has been used in many areas were there has been difficulty in determining appropriate design flood events. This method was approved by the Project Manager and Barcaldine Regional Council as an appropriate approach under the circumstances. One advantage of using an historical event is that members of the community can more easily understand the impact of proposed mitigation options, having had first-hand experience of the real flood event.

It is however recommended that additional stream gauge data is collected for future events to assist in defining design flood events at a future date.

8.2 Flood hazard review

Estimation of hazard involves a number of factors although a key component is stability of pedestrians and vehicles. The primary factors affecting stability of both pedestrians and vehicles are flow velocity and depth of flow. The relationship between depth and velocity for each of the hazard categories varies depending on the person or vehicle involved. Plate 1 from *Floodplain Management in Australia* (CSIRO, 2000) describes each of the hazard categories as outlined in Table 8-1.

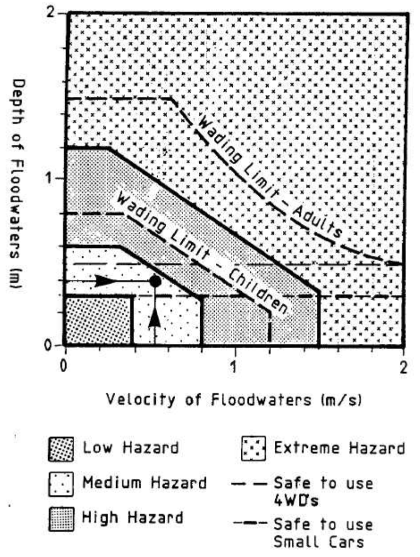

Plate 1 — Flood Hazard Definition

Table 8-1 Hazard category descriptions

Hazard Category	Description
Low	• There are no significant evacuation problems; • If necessary, children and elderly people could wade to safety with little difficulty; • Maximum flood depths and velocities along evacuation routes are low; • Evacuation distances are short; • Evacuation is possible by sedan-type motor vehicle, even a small vehicle; • There is ample time for evacuation; and • Evacuation routes remain open for at least twice the time required for evacuation.
Medium	• Fit adults can wade to safety, but children and elderly may have difficulty; • Evacuation routes are longer; • Maximum flood depths and velocities are greater; • Evacuation by sedan-type vehicle is possible in the early stages of flooding, after which 4WD vehicles or trucks are required; and • Evacuation routes remain trafficable for at least 1.5 times as long as the necessary evacuation time.
High	• Fit adults have difficulty in wading to safety; • Wading evacuation routes are longer again; • Maximum flood depths and velocities are greater (up to 1.0m and 1.5m/s respectively); • Motor vehicle evacuation is possible only by 4WD vehicles or trucks and only in the early stages of flooding; • Boats and helicopters may be required; and • Evacuation routes remain open trafficable only up to the minimum evacuation time.
Extreme	• Boats and helicopters are required for evacuation; • Wading is not an option because of the rate of rise and depth and velocity of floodwaters; and • Maximum flood depths and velocities are over 1.0m and 1.5m/s respectively.

A preliminary flood hazard map for the April 1990 flood event covering the town area is presented in Figure 10. Most of the town centre lies in the extreme hazard zone. The velocities are in the order of 0.4 – 0.8 m/s however the depths (refer Figure 7C) are sufficient to render the hazard either high or extreme.

This preliminary hazard map should be reviewed by Council to identify any additional risks that may influence the level of hazard to residents.

8.3 Impact of existing road and rail links

Three MIKE 21 model runs were used to determine the impact of the existing road and rail links on the flooding regime around Alpha. The three scenarios modelled were:

- Rail link removed,
- Road link removed, and
- Road and rail link removed.

Figures M1a/b, M2a/band M3a/b show the peak water levels and level difference maps for each of the modelled scenarios. It can be seen from the maps that the embankments have an insignificant impact on the peak water levels and extent for the April 1990 event. With reference to the existing 'base' case, flood waters initially flow through the railway bridge at the end of Moore Street. As the levels rise in the early stages of the event, lower sections of the railway to the east begin to be overtopped. Thus, during the rising stages of the flood, some attenuation occurs at the railway embankment but it is quickly inundated and any hydraulic impact is dissipated. Likewise, flow is initially directed along the natural floodway between Moore Street and the Capricorn Highway due to the highway embankment. However, as the levels rise, the highway embankment is overtopped and any impact is again dissipated by the time peak water levels are reached.

8.4 Environmental and planning considerations

An assessment of the current environmental conditions has been undertaken. The existing environmental condition of the floodplain is detailed in the following sections.

8.4.1 Climate and rainfall

Alpha experiences a summer rainfall pattern with the highest rainfall averages occurring in January and February. The mean maximum temperature is 30° and the mean minimum is approximately 15° (with reference to Barcaldine and Emerald records).

8.4.2 Land use

According to Scott and Furphy (1991) the population of Alpha in 1991 was approximately 500. From discussion with Council the population is now approximately 360 (2007). There are about 150 houses and 16 businesses most of which are located in Shakespeare Street. About 70% of the houses and all but one of the businesses are located in the Alpha Creek floodplain. The town is surrounded by bushland and grazing is the dominant land use surrounding the town.

8.4.3 Flora and fauna

The dominant remnant regional ecosystem (RE) in the project area is RE 11.3.2, which has been classified as *of concern* under the EPA's Regional Ecosystem Mapping. In addition, there is the potential presence of RE 11.3.1, an *endangered* remnant RE (refer to RE Map in Appendix C). The classification system for REs is summarised in Table 8-2.

Table 8-2 Regional ecosystem classifications

RE type	Characteristics
Endangered	• Less than 10% of the pre-clearing extent remains; or • 10-30% of the pre-clearing extent remains (but the area of remnant vegetation is less than 10,000 hectares)
Of concern	• 10-30% of the pre-clearing extent remains; or • More than 30% of the pre-clearing extent remains (but the area of remnant vegetation is less than 10,000 hectares)
Not of concern	• 30% of the pre-clearing extent remains and the area of remnant vegetation is more than 10,000 hectares.

Source: Sattler & Williams 1999.

The RE 11.3.2 is associated with alluvial plains in river and creek flats and features such vegetation communities as *Eucalyptus populnea* woodland. The species *Homopholis belsonii* is associated with this RE as is some unmapped patches of low *Acacia harpophylla* (EPA 2007). RE 11.3.1 is associated with dominant *Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains (EPA 2007).

A Wildlife Online data search was undertaken for the project area using a point search with a defined 2km radius around the town of Alpha. From this search 41 species were recorded with no species being listed as "Endangered, Vulnerable or Rare" under the *Nature Conservation (Wildlife) Regulation 2006* of the *Nature Conservation Act 1992*. Wildlife Online records show that *Eucalyptus populnea* is present within the project area, as is *Aristida* spp (grass understory commonly associated with *Eucalyptus populnea*) (RGB&DT 2007), classifying these two (2) species as Common. However, the Wildlife Online search found no presence of *Homopholis belsonii* or *Acacia harpophylla*.

Other Common vegetation communities as listed under the *Nature Conservation Act 1992* from the Wildlife Online search include *Callitris, Cheilanthes distans, Sida, Sida subspicata, Acacia macradenia, Corymbia tessellaris, Eucalyptus melanophloia, Nicotiana, Fimbristylis dichotoma, Eragrostis lanicaulis, Heteropogon contortus, Bothriochloa decipiens* and *Dactyloctenium radulans*. No specific records of *Homopholis belsonii* or *Acacia harpophylla* were identified during the Wildlife Online search.

Listed threatened species and communities

An EPBC Act Protected Matters search was undertaken to determine the occurrence or likely occurrence of nationally threatened species occurring within the project area. The search identified one (1) threatened community and ten (10) threatened species potentially inhabiting the area. These are listed in Table 8-3. These searches are supported by Wildlife Online data.

Table 8-3 EPBC Act Protected Matters Report – Flora and Fauna

Species	Status	Habitat Associations	Likely Occurrence	Project Impact
Threatened Ecological Communities				
Acacia harpophylla dominant and co-dominant (Brigalow)	Endangered (EPBC)	A tree usually 5-20m high that can form dense scrubs or low forests, generally in clay loam soils (RBG&DT 2007).	Wildlife Online records have not noted its presence. However, the RE 11.3.2 (associated with *Eucalyptus populnea* – which was found in the Wildlife Online records) exhibits some unmapped patches of *Acacia harpophylla*. Therefore, there is a low to moderate likelihood that *Acacia harpophylla* is present within the project area.	If found in the project area, avoid extensive clearing of this endangered ecological community.
Threatened Birds				
Geophaps scripta scripta (Squatter Pidgeon – southern sub-species)	Vulnerable (EPBC) (NCA)	Tropical, open and dry woodlands/grasslands of north-eastern Australia (Marchant & Higgins 1990). Prefer areas of sandy soil dissected by low gravely ridges, with short grasses and adjacent to water (Morcombe 2000).	Not identified in project area during Wildlife Online searches. However, short grass cover is evident in the area (Wildlife Online), which may attract the Squatter Pidgeon to its preferred habitat.	Minimising the extent of vegetation clearing, and avoiding trampling of grasses.
Rostratula australis (Australian Painted Snipe)	Vulnerable (EPBC) (NCA)	Freshwater (occasionally brackish) wetlands. Mostly south east Australia. Possibly part-migratory moving north into Queensland in summer (Higgins and Davies 1996)	Low likelihood of occurrence due to lack of suitable preferred habitat within project area.	Lack of suitable habitat for *Rostratula australis* presence so no impact on this species.
Neochmia ruficauda ruficauda (Star Finch – eastern and southern)	Endangered (EPBC) (NCA)	Inhabits tall grass and reed beds associated with swamps and watercourses. Also in grassy woodlands, open forests and mangroves (EPA 2007).	Low to moderate likelihood that the Star Finch occurs in the area, as there is suitable habitat for the species. However, Wildlife Online records have not registered any presence of Star Finch.	Levee construction should avoid clearing any habitat of the endangered Star Finch where possible. Avoid clearing and trampling of grasses adjacent to the watercourse.

Species	Status	Habitat Associations	Likely Occurrence	Project Impact
Poephila cincta cincta (Black-throated Finch – southern)	Endangered (EPBC) Vulnerable (NCA)	Eucalypt woodland and riparian vegetation (paperbark and wattle shrubland), with dense understory of grass and/or shrubs (DEC 2005).	The Black-throated Finch – southern has a low to moderate probability of inhabiting the project area (appropriate habitat). However, Wildlife Online records have not noted its presence.	Ensure that clearing is not extensive to cause adverse impacts to this species.
Threatened Reptiles				
Egernia rugosa (Yakka Skink)	Vulnerable (EPBC) (NCA)	Occurs near the coast and in the sub-humid to semi-arid eastern interior of Qld, (Wilson & Knowles 1988; Cogger 2000). Usually found in open woodland (Wilson & Knowles 1988; Cogger 2000). Yakka Skinks inhabit dense ground vegetation, hollow logs, and cavities in root systems below the ground (Wilson & Knowles 1988; Cogger 2000).	This species prefers open woodland habitat, which is present within the area with species such as *Eucalyptus populnea*. The Yakka Skink was not identified during the Wildlife Online search; however there is a moderate probability that this species inhabits the area.	Need to ensure that the smallest area of vegetation is cleared for levee construction to ensure this species is not adversely impacted. If desilting of the creek was to occur as an alternative mitigation option, there is the potential to affect habitat further by the removal of ground vegetation, hollow logs, and cavities in root systems below the ground.
Furina dunmalli (Dunmall's Snake)	Vulnerable (EPBC) (NCA)	Inhabits the Brigalow Belt region in the south eastern interior of Qld, *Acacia harpophylla* forest and woodland growing on cracking black clay and clay loam soils (Covacevich *et al*. 1988; Cogger *et al*. 1993).	Dunmall's Snake was not identified in the Wildlife Online search. Its preferred habitat may be present within the project area, as RE 11.3.2 (the predominant RE evident in the project area) features some unmapped patches of *Acacia harpophylla* – the preferred habitat of Dunmall's Snake.	Dunmall's Snake may occur in the area, but clearing of its habitat needs to be minimised to ensure that no adverse impacts occur.

Species	Status	Habitat Associations	Likely Occurrence	Project Impact
Paradelma orientalis (Brigalow Scaly-foot)	Vulnerable (EPBC) (NCA)	Inhabits the Brigalow Belt region, east of the Great Dividing Range in south-central Qld, in open forest habitats in remnant Brigalow (*Acacia harpophylla*) woodland with sparse tussock grasses on grey cracking clay soils (Cogger *et al*. 1993). Shelters under surface debris or in grass hummocks (Wilson & Knowles 1988).	Brigalow Scaly-foot was not identified during the Wildlife Online search. Its preferred habitat may occur in the area, as RE 11.3.2 exhibits some unmapped patches of *Acacia harpophylla*. Therefore, low to moderate likelihood of occurrence.	Low to moderate likelihood of occurrence in the project area so habitat clearing needs to be minimised as much as possible.
Migratory Terrestrial Species – Birds				
Haliaeetus leucogaster (White-bellied Sea-Eagle)	Migratory	Occurs in coastal areas over islands, reefs, estuaries, seasonally flooded inland swamps, lagoons, and floodplains (Morcombe 2000).	Low to moderate likelihood of suitable habitat in area – unlikely to occur in the area.	Unlikely to occur in the area so no impact.
Merops ornatus (Rainbow Bee-eater)	Migratory	Grasslands, open forest and woodlands, also in loamy soft soil enabling the species to burrow and nest (Morcombe 2000).	Low to moderate likelihood that there is favourable habitat in the area, and as this species is migratory it could inhabit the project area at various times of year.	Low to moderate likelihood that species is present in the area, so avoid trampling grass species during levee construction.
Gallinago hardwickii (Latham's Snipe, Japanese Snipe)	Migratory	Low vegetation in wetland areas such as sedges, reeds, heaths, salt marsh, and irrigated crops (Morcombe 2000).	This species was not identified in the Wildlife Online records. However, the watercourse in the project area may exhibit vegetation that might be suitable for this species.	Avoid clearing vegetation around the watercourse as much as possible.

Table Notes:

(NCA)= *Nature Conservation Act 1992* (Queensland Government)
(EPBC)= *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth of Australia)

The project area has been disturbed by human activities – agriculture and the construction of the town and associated infrastructure. Most of the town area has been cleared of vegetation to make way for development.

8.4.4 Surface water quality

The project area lies in the upper reaches of the Burdekin catchment. Two main tributaries drain the catchment, the Burdekin River flowing from the north and the Belyando from the south, which join at the Burdekin Falls Dam. No information was available for this study regarding water quality.

8.4.5 Soils and topography

Sandy, alluvial soils are the predominant soil type within the area.

8.4.6 Air and noise quality

Air and noise monitoring has not been undertaken for this assessment. Given the predominant land use in the area (ie rural), no major air and noise issues are expected.

8.4.7 Cultural heritage

An indigenous cultural heritage investigation and native title claimants search has been undertaken. The native title claimants search identified that native title claims have been lodged for the area and carry an active status (Wangan & Jagalingou People).

No listings on the Australian Heritage Database or the Queensland Heritage Register have been recorded for the town of Alpha.

8.5 Scott and Furphy report

The report entitled “Western Queensland Towns Flood Study”, Scott and Furphy (1991), contains a section reviewing the impact of the 1990 flood event upon Alpha. A copy of this report is provided in Appendix D. This report was used as a reference material throughout the current study.

9. Existing and continuing flood risks

9.1 Identification of flood risks

There are a number of parties that would be directly affected by the risk and severity of flooding from Alpha Creek. These include:

- Landholders and local residents
- Local business owners
- Federal government
- State government
- Local shire council
- Industries/businesses
- Bureau of Meteorology
- Emergency services (fire, police, ambulance, SES)
- Department of Natural Resources and Water
- Queensland Rail
- Department of Main Roads

The elements that are at risk during a large Alpha Creek flood event include:

- Individual people using the floodplain
- Industries/businesses on the floodplain (ie flooding may affect production)
- Built assets and natural resources
- Public property such as the showground
- Private property and infrastructure including residential and commercial properties
- Public infrastructure including water supply, sewerage, roads, railway, electricity, telephone
- Natural resources such as land and forests or bushland
- Floodplain ecology

The potential risks include:

- Loss of life or injury;
- Risk to community health from contaminated flood waters
- Isolation leading to inability to access medical help and supplies
- Difficulty of evacuation and movement within the town
- Damage to property, including houses and contents, sheds, business premises, equipment etc
- Damage to local infrastructure including water supply, road and rail links, air strip etc
- Health risks due to the inundation of septic tanks resulting in surcharging of these tanks
- Damage to the surrounding environment

These existing risks will continue unless an appropriate mitigation option is selected to reduce flooding within the town. Damage to infrastructure outside the town, including the road and rail links, is likely to continue to be a risk during major flood events.

9.2 Flood prediction and warning procedures

9.2.1 Flood warning stations

According to the BoM Flood Warning System website the Burdekin ALERT Flood Warning System was completed in 1990 as a cooperative project between the Bureau of Meteorology and the Burdekin Shire Council. The system comprises of a network of rainfall and river height stations which report via VHF radio to a base station computer located in the Council office in Ayr. The balance of the network consists of volunteer rainfall and river height observers who forward observations by telephone when the initial flood height has been exceeded at their station (BoM). Refer Appendix E for the BoM network map.

At typical Flood Warning Stations, volunteers observe daily rainfall and river height and forward the data to the BoM through a Remote Observer Terminal (ROT). A ROT is a small device attached to a normal telephone line. The observer calls a Freecall number and enters the data into the ROT. If the river height reaches a predetermined threshold the observer may be required to increase the frequency of observations.

When the BoM received the river height data, it is checked to determine if a flood warning should be issued. The data processing and subsequent issuing of flood warning have been automated, enabling Counter Disaster Organisations to access the warnings within 30 minutes of the BoM receiving the data.

According to the BoM Flood Warning System website the classifications of flood warnings are defined to be:

- **Minor**: causing inconvenience such as closing of minor roads and the submergence of low level bridges and makes the removal of pumps located adjacent to the river necessary.
- **Moderate**: causing inundation of low lying areas requiring the removal of stock and/or the evacuation of some houses. Main traffic bridges may be closed by floodwaters.
- **Major**: causing inundation of large areas, isolating towns and cities. Major disruptions occur to road and rail links. Evacuation of many houses and business premises may be required. In rural areas widespread flooding of farmland is likely.

When a flood warning is issued, the data is automatically uploaded to the Flood Warning System Website (www.bom.gov.au/hydro/flood). This is readily accessible by members of Counter Disaster Organisations and the public for both disaster planning and other preventative measures. It is important that members of the Alpha Counter Disaster Organisation are aware of this facility. Its many features could assist with the planning for impending floods.

9.2.2 Existing situation in Alpha

Alpha is situated within the upper reaches of the Burdekin River Flood Warning Network. Two flood warning stations serve Alpha; the Rivington station approximately 40km upstream of Alpha and the Alpha station located on the Arthur Palmer Bridge in town. Both the Alpha and Rivington stations are manually read river stations. Downstream at Violet Grove is a telemetry station. The Alpha station commenced in September 1956 and the Rivington station commenced in August 1991.

Plates 2 and 3 illustrate the Alpha station. Table 9-1 shows the flood warning classification levels for the stations.

Plate 2 – 'Alpha' River Height Flood Warning Station
(Photograph courtesy of Bureau of Meteorology)

Plate 3 – 'Alpha' River Height Flood Warning Station

Table 9-1 Flood warning classification levels

Classification	Alpha Creek Bridge at Rivington (m)	Arthur Palmer Bridge at Alpha (m)
First report	2.0	2.0
Bridge height	2.2	11.2
Minor	3.5	7.0
Moderate	6.0	7.5
Major	7.0	8.0

During the April 1990 event only the Alpha station was in operation. Thus, accurate prediction could not be made regarding the expected peak level of flooding and the timing. Residents were reliant on receiving and interpreting informal upstream reports. According to Scott and Furphy, evacuation commenced well before the formal alerts were issued with evacuees taken to higher ground in the western part of the town.

It is understood that during the recent January 2008 event, there was some confusion regarding responsibility for reading and forwarding information from the Rivington manual gauge and that this hindered flood warning and emergency management planning for Alpha.

9.3 Flood damage assessment

ANUFLOOD is an interactive computer package used to assess the cost of flood damage within an existing developed catchment. The program is based on research undertaken by the Centre of Resource and Environmental Studies (CRES) at the Australian National University.

The program requires the following input to assess estimates for annual average damage:

- Stage/damage characteristics;
- Survey of ground and floor levels; and
- Flood frequency information.

Due to the inability to develop design flood events for this study, the ANUFLOOD damage assessment has not been able to be carried out. However if design event modelling is revisited following collection of more stream gauge data, then the flood damage assessment should also be revisited.

10. Assessment of mitigation options

10.1 Structural measures

A range of structural measures, including those proposed by the Study Working Group and local residents, have been modelled to assess their effectiveness in reducing impacts of flooding within the town. The measures assessed are detailed in Table 10-1 below and are shown diagrammatically in Figure M0. The assessments have been based on the 'levee collapsed' topography during the April 1990 event. Although the levee is considered to have aided in evacuation, it has been shown that the peak water levels are not affected by the inclusion of the levee.

Table 10-1 Mitigation options for consideration

Option	Figure No	Description
1	M1	Removal of Central Railway (embankment and structures)
2	M2	Removal of Capricorn Highway (embankment and structures)
3	M3	Removal of both Central Railway and Capricorn Highway (embankment and structures)
4	M4	Replacement of/addition to existing railway culverts to increase waterway area
5	M5	Levee construction along Alpha Creek overbank from the Capricorn Highway to the Central Railway (Location A to Location B)
6	M6	Levee construction along Alpha Creek overbank from the Capricorn Highway to the Central Railway extended parallel and to the north of the Central Railway (Location A to Location C)
7	M7	Excavation of overbank area D of Alpha Creek north of Alpha
8	M8	Dedicated floodway between Swinbourne and Moore Streets from Alpha Creek at the Road Bridge extended to the creek – 10m base, side slopes of 1 in 4, depth 2 to 4m
9	M9	A combination of the dedicated floodway and levee A to B
10	M10	Introduction of creek channel maintenance from the Capricorn Highway bridge to directly north of Neil Street
11	M11	Introduction of creek channel maintenance from south of Alpha extending past Alpha Town

The results of the mitigation modelling are presented in Figures M1 to M11. Part 'A' presents peak water levels whilst Part 'B' illustrates the difference in peak water levels from the Existing Case for the April 1990 event.

It can be seen from the figures that the large volume of water in the floodplain during a significant event renders most of the physical measures considered relatively ineffective in reducing flooding in Alpha or adversely impacts on other residents. However, it is important to consider that these mitigation options have been assessed against the April 1990 event only due to the inability to develop design events. This is a significant flood event with an estimated return period of 100 to 200 years (Scott and Furphy, 1991). It is possible that some of the options may have a more beneficial result under the more frequent, lesser magnitude events.

Options M1 to M3 – Removal of Capricorn Highway and Central Railway embankments

As discussed in Section 8.3, the highway and railway embankments do have an effect on flow paths and depths in the initial stages of an out-of-bank flood event. However, the embankments are quickly overtopped and the impacts are dissipated.

With both the rail and road embankments removed the flow patterns are not significantly different from the Existing Case (ie current state of development). Although the highway embankment directs more water along the Moore Street/Swinbourne Street natural floodway, with the embankment removed this remains a major flow path. The railway bridge does attenuate flow leading to increased water levels upstream of the bridge in the order of 300mm whilst flood waters are rising. However the peak flood extent and peak water levels are not significantly different as the railway is overtopped.

Scott and Furphy (1991) considered the railway to be a major impediment to drainage of flood waters. The community generally agreed that an increase in drainage area through the railway embankment would be desirable but the removal of both embankments would not be practical or an effective solution. The model results show that removal of the embankments is only likely to be beneficial for flood events with peak water levels lower than the road and rail embankment levels. Under larger events overtopping of these structures occurs and removal does not lower peak water levels.

Option M4 – Additional railway culverts

To test the impact of additional waterway area under the rail embankment, additional culverts were added. The additional culverts consisted of 10/3600x3000, 10/3600x2400 and 10/3600x2100 in the vicinity of Moore Street and the Capricorn Highway (replacing the existing trestle bridge opening). In addition 10/3600x1800 were included east of the rail yard. These culverts in total provided approximately 4 to 5 times the existing waterway area. The area provided would be comparable with the increase suggested in the Scott and Furphy report.

Increasing the waterway area through the railway embankment only reduces flood levels upstream of the embankment during the rising stage of flood events. Similarly to removal of the rail/road embankments, water levels are reduced in the order of 200mm. However, the peak inundation extent and peak water levels are not significantly different due to overtopping of the railway.

The general response from community consultation was positive and considered this a potential option for consideration. Scott and Furphy (1991) also suggest that the railway bridge acts to ‘dam’ the flood waters in the natural floodway, impeding drainage of flood waters. The modelling has demonstrated that this happens to a degree in the rising stages of the flood event. However, the overall impact on peak flood levels reached in town is not significant.

The benefit of Options M1 to M4 is reduced, particularly under larger flood events, by flood waters backing up into the town from the creek on the downstream side of Alpha.

Options M5 and M6 – Levee construction

In order to prevent or at least inhibit flood waters entering the town area, two levee alignments were considered, being:

- A to B – from the hospital on the southern edge of town along Alpha Creek to the railway bridge.
- A to B to C – from the hospital along Alpha Creek to the railway bridge and across the north of town parallel to the railway, thus surrounding the town.

These configurations are shown in Figure M0. The levees have been modelled so as not to be overtopped by the 1990 flood event and connect into naturally occurring high ground on the western side of town.

With Levee A to B in place, inundation of the town is delayed by approximately 4 hours. As inundation occurs, floodwaters enter from the north-east side of town from water backing up from downstream. The loss of floodplain and subsequent increased flow in the channel exacerbate the downstream 'choking' effect. This causes further backing up, reducing the mitigating effect of the levee. The peak flood levels experienced in town area are approximately 0.3m to 0.9m lower than the Existing Case. The peak water levels experienced on the eastern bank are up to 0.8m deeper which may impact on private property and would impact upon the flood immunity of the road and rail bridges.

The extended levee (A to C) surrounding the town prevents flood waters from entering the central town area throughout the flood event. The removal of this overbank area diverts more water to the eastern bank, increasing depths by approximately 1metre. The extent of inundation does not increase significantly due to the topography although additional private properties are potentially inundated. North of the levee bank, peak water levels decrease by approximately 300mm.

The levee would need to be constructed to a height of 2 to 3m in order to protect from a flood event with a similar magnitude to the April 1990 event.

The general feedback from the community consultation on this option was agreement in its ability to protect the centre of town but concern regarding where the redirected floodwaters are going. The model results show that flood waters are being redirected along the east bank of the creek and that significant increases in peak water levels are experienced.

The risks and costs associated with such a high levee embankment being constructed need to be thoroughly considered. It is not proposed that this is an acceptable mitigation solution.

Option M7 – Excavation of overbank area

To assess the benefit of a wider channel area, excavation of overbank area D, as shown in Figure M0, was undertaken. The volume of excavation simulated was up to 3 m deep and covered an area of approximately 0.2 km^2. The resultant peak water levels were marginally reduced in town (approximately 0.1m) but not significantly. Flow patterns and flood extent are not affected.

The general response from community consultation was positive and considered this a desirable way forward. The creek is generally considered to be in need of 'clearing'. However, it was considered it would have more of an impact on the flood levels than what the model has demonstrated. Significant approvals are also likely to be required to undertake these works.

Option M8 – Dedicated floodway between Swinbourne and Moore Streets

A floodway channel between Swinbourne Street and Moore Street was considered as a measure to contain and convey floodwaters through the town under smaller flood events. A channel of 10m base width, 1 in 4 side slopes and depth of 2 to 4m was adopted. It was assumed that this channel would be grass lined.

During a significant flood event, the floodway would direct water along the lower land adjacent to the highway and away from the lower part of the town. However, breakout would still occur at the southern end of Tennyson and Scott Street leading to inundation of the town. In addition, the capacity of the floodway was exceeded by the 1990 modelled event in the proximity of the railway embankment leading to inundation of the town from the west. The ultimate peak levels are not significantly different from the Existing Case. Encouragement of water into this floodway potentially inhibits evacuation and effectively 'traps' residents on the eastern side unless alternative routes of egress can be provided. Public safety issues would need to be carefully considered if the concentration of flow leads to high velocities, even during the more frequent flood events.

Option M9 – Dedicated floodway between Swinbourne and Moore Streets plus Levee A to B

The flooding mechanisms and changes in peak water levels associated with this scenario are very similar to the Levee A to B option. Flood waters still enter the town from the north-east however, under this option, the floodway fills from the downstream end as flood waters back up. This proposed combination does not significantly change the flood inundation of the town area.

Options M10 and M11 – Introduction of creek channel maintenance

Maintenance of the creek channel was represented by a reduction in channel bed levels of 0.5 m to simulate removal of deposited silt. Two scenarios were considered; dredging from the Capricorn Highway bridge to directly north of Neil Street and dredging from south of Alpha extending north past Alpha Town.

The channel maintenance has an insignificant impact on flow patterns, peak water levels and flood extent for a significant event such as the 1990 flood. It is possible that for the more frequent flood events this may have a significant impact. The general view from the community consultation was that the creek channel was need of clearing of debris/obstructions and desilting. However, concern was expressed regarding the removal of trees and destabilisation of the banks.

10.2 Non-structural measures

A number of non-structural measures could be considered to minimise the impact of flooding on the town. These include:

- Initiating an automated flood warning system
- Augmenting the existing flood warning system
- Developing a community flood awareness program
- Implementing planning procedures to prevent development in flood prone areas
- Raising of flood prone properties
- Implementing "Buy back" scheme of flood prone properties

While these measures may not prevent flooding or reduce flood levels in the affected areas, they will help to minimise the effects of flooding.

10.2.1 Augmenting existing flood warning system

The flood warning system in the vicinity of Alpha currently relies heavily upon manual reading and reporting of stream gauges both upstream of the town and in the town itself. During the April 1990 and the January 2008 events, upstream information from the Rivington manual station was not available and therefore advice regarding expected flood peaks and timing were not readily available. With the limited warning time available before upstream flood waters reach Alpha, any delays in providing advice should be minimised. In particular, with the Rivington gauge operating effectively there would be greater accuracy in peak level and timing predictions. Although in 1990 residents had sufficient evacuation time, many did not move their personal effects as they did not expect the level to rise as much as it ultimately did.

To improve this situation, automated flood warning stations at Rivington and Alpha could be installed to enhance the current warning for imminent flooding. The principle advantage of an automated station over the current flood height gauges is that the automated station does not rely on a manual reading of the gauge. Currently, if the persons nominated to record the gauges are not in the area during a flood event or new operators have taken over and are not fully aware of their responsibilities or aware of flooding in the area, then the readings would not be received by the BoM's flood warning system. An automated system would eliminate this uncertainty from the flood warning procedure.

An automated system could also enable the URBS model to be calibrated with more accuracy and could be incorporated into BoM's Burdekin River flood forecasting model. This would assist in providing a more accurate forecast of potential flood levels and timing of flood peaks.

10.2.2 Community awareness and training

Community awareness is important for a town subject to potential significant flooding. It should not be assumed that all existing residents were present for the last major flood; some may not be aware of the nature or extent of flooding. Maintaining community awareness ensures that all residents, and in some cases visitors, have procedures in place in the event of an impending flood. This may serve to reduce damage or possibly injury or death. Community awareness can be increased through the preparation and release of a flood warning brochure to residents and by holding local information sessions. In addition, Scott and Furphy recommended the installation of flood markers to increase awareness of the flood prone areas.

Training may also be required for the members of the disaster response organisation in Alpha, particularly in regard to the interpretation of flood warning information forwarded from the BoM. The information from the BoM can be important in the planning of the response to impending flooding and those responsible for coordinating evacuations should be fully aware of the available forecasting tools.

10.2.3 Planning control measures

Planning procedures could be implemented to prevent new development in areas subject to flooding. As much of the area surrounding Alpha is subject to inundation, preventing all development may not be practical. The filling of lots could have an adverse effect on other properties if flood waters are redirected. In this case, development approval may include conditions to facilitate the passage of floodwaters without inundation to floor space. Alternatively, particular types of residences (eg highset houses) could be permitted only on flood affected lots.

10.2.4 Raising of flood prone properties

Given the population of Alpha, a viable mitigation option is the raising of flood prone dwellings. Although the majority of town would be affected by this, the overall cost could be comparable to the structural options. A decision would be required as to the immunity required. Given the lack of design flood data, referencing the historic 1990 event is considered an appropriate choice.

10.2.5 Implementing "Buy back" scheme of flood prone properties

In some situations, the implementation of a "buy back" scheme is a viable mitigation option. However, given the extent of flooding that occurs in Alpha, the buy back would include a majority of the population and therefore have a significant adverse social impact on the town. This option is not considered to be viable in Alpha.

10.3 Cost considerations

It is important to not only review the mitigation options in terms of impact on flooding, but also in terms of infrastructure cost. Preliminary Cost estimates for the physical and non-physical mitigation measures have been prepared and are documented in Appendix F. These cost estimates have been used to assist in determining an approximate cost-benefit for each option.

Disclaimer

These presented cost estimates are an initial indicative cost estimate only developed for the project and should be subject to further refinement.

Cost estimates have been prepared based on preliminary quantities and historic rates and will require updating as the design progresses.

We note that any opinion or estimate of costs by Connell Wagner has been made on the basis of Connell Wagner's experience and qualifications and will represent Connell Wagner's judgement as an experienced and qualified professional engineer, familiar with the construction industry. Connell Wagner however, has no control over the cost of labour, materials, equipment or services furnished by others, or over Contractor's methods of determining prices, or over competitive bidding or market conditions. Connell Wagner therefore, cannot and does not guarantee that proposals, bids or actual construction costs will not vary from Connell Wagner estimates.

10.4 Environmental considerations

A range of potential environmental impacts associated with the construction and operational phases of the proposed mitigation options for the Alpha Town Flood Mitigation Study have been assessed and are discussed below. Mitigation options considered in this assessment include the construction of levees and the desilting of the Alpha Creek bed as these are considered likely to have the greatest environmental impact.

Data used for the assessment of environmental impacts was obtained from several sources. These included:

- Wildlife Online – Environmental Protection Agency (EPA)
- Regional Ecosystems mapping (EPA)
- Cultural Heritage Register (EPA)
- Native Title Register (EPA)
- Barcaldine Regional Council planning scheme

10.4.1 Land use

The levees will cover a number of "land use zones" which include:

- Industrial
- Urban
- Open Space and Recreation
- Commercial

These "land use zones" are depicted in the Barcaldine Regional planning scheme. Each "land use zone" is to protect environmental elements of the Barcaldine Regional through appropriate measures to avoid impacts as a result of "development" activities. These environmental elements are outlined in the sections below as they relate to levee construction for the town of Alpha.

10.4.2 Flora and fauna

The construction of levee banks could potentially impact on the flora and fauna within the project area. The Barcaldine Regional planning scheme specifies that "development" should retain vegetation for the:

- Protection of scenic quality
- Protection of general habitat
- Protection of soil quality
- Establishment of open space corridors and networks

In addition, the planning scheme stipulates that "development" should ensure the maintenance of riparian areas and water quality in relation to "watercourses".

If levee construction was to occur, there is the potential for some habitat loss and erosion, causing increased sedimentation of the watercourse adjacent to where the levees will be constructed. The Wildlife Online search identified only Common species listed under the *Nature Conservation Act 1992*, which suggests that there is only a low likelihood that the threatened species identified in the EPBC Protected Matters Report are present in the project area. Therefore, vegetation of conservation status is unlikely to be impacted as a result of the project works.

The alternative mitigation option of desilting the creek could impact the floodwater ecology. Potential mitigation measures have been recommended below:

- Limit clearing and disturbance
- Avoid trampling of grass species as much as possible
- Reduce the area to be cleared or adversely impacted during the detailed design stage
- Rehabilitate any disturbed areas as soon as practicable
- Implement a Weed Management Plan
- Protect remaining habitat from further clearing and development

It is concluded that if appropriate mitigation measures are used, the proposed project will not have an unacceptable impact on flora and fauna in the project area.

10.4.3 Surface water quality

Impacts on water quality may occur due to increased erosion and sedimentation from the pre-construction works and possible spills of hazardous materials such as oils and fuels. Water quality may be altered during the construction of the levees, with increased sediment presence in the adjacent watercourse. If desilting is used, sediment may become unsettled and reduce water quality.

Other potential impacts on surface water quality during the construction phase are as follows:

- Hydrocarbon pollutants from vehicles and machinery
- Toxic materials such as asphalt prime, solvents and cement slurry
- Litter

Changes to water quality during the operational phase are not expected to be significant.

The following mitigation measures are recommended:

- Temporary erosion and sediment control measures to be implemented
- Revegetation of cleared areas using native species as soon as practicable
- Limit vegetation clearing as much as possible
- Cover and/or bund toxic materials and waste
- Provide on-site waste receptacles

10.4.4 Soils and topography

The topography of the project area will be altered with the height of the levees being approximately 3m high. The levees will have more of a noticeable impact along the stretch from B to C but may be less noticeable along the stretch from A to B adjacent to the creek line. Desilting will not significantly impact the topography of the project area.

The construction of levee banks will disturb the existing soils, which may cause erosion if appropriate erosion and sediment control measures are not implemented. This impact will be expected to be low if appropriate measures are implemented during construction. A number of mitigation measures have been recommended:

- Limit soil disturbance during the construction phase
- Implement temporary erosion and sediment control measures
- Revegetate cleared areas progressively with native species to reduce erosion
- Avoid earthworks after rainfall events

10.4.5 Air and noise quality

During construction, dust may affect the air quality within the area slightly. However, if dust suppression measures are implemented, air quality impacts are not likely to be significant. In addition, air quality is not likely to be impacted during the operational phase of the project. The dust suppression measures recommended for the construction phase of the project are:

- Watering of the site and stockpiles
- Revegetating as soon as practicable
- Avoiding dust producing activities on high wind days
- Locating stockpile sites away from residences
- Inform residents that air quality may change slightly during construction

Noise levels are likely to increase during the construction phase, but will not be significant during the operational phase of the project. To ensure that residents are not adversely affected by construction noise, a number of management strategies are recommended:

- Use the most effective and efficient machinery available to reduce noise
- Silencing equipment to be fitted to construction machinery
- Limit construction works to day-time hours
- Consult with residents

10.4.6 Cultural Heritage

Barcaldine Regional Council will need to notify all native title claimants of the proposed works, as specified under section 24KA of the *Native Title Act 1993*.

The Barcaldine Regional planning scheme stipulates that “development” should ensure the protection and maintenance of places and items of cultural heritage. Potential mitigation measures to ensure protection of cultural heritage may include:

- Ongoing consultation with Traditional Owner representatives
- Project works to be undertaken in accordance with the *Aboriginal Cultural Heritage Act 2003* (ACHA)
- If applicable, implement two Cultural Heritage Mitigation Agreements (CHMA), which may include requirements for monitoring construction, specifically excavation activities, and management options for located artefacts within the project area
- Construction staff to be made aware of the importance of the ACHA and the Duty of Care

10.4.7 Recommendations

Both of the levee options have the potential to exhibit some or all of the environmental impacts outlined above. However, levee A to B will impact less on flora and fauna than levee B to C as levee B to C will not follow the natural creek line (where the vegetation in the project area is mainly located). The levee option chosen should be the most effective at restricting overland flow during floods. If appropriate mitigation measures are implemented during construction, the potential environmental impacts discussed above will be able to be minimised.

10.5 Social impacts

Given the extensive existing impacts of regular flood events on the township of Alpha, it is important to consider the social impacts of the various mitigation options being explored. While considering both positive and negative impacts issues examined will include:

- Existing patterns of movement in the community, including access to education, businesses, medical facilities and emergency services
- Impacts on capacity to increase population and/or local development
- Continued use of local facilities and services, including transport infrastructure.

Overriding issues such as 'down' time of the town, the economic and psychological cost of damage, and adequacy of warnings also raise social impact considerations. A Social Impact Summary is provided in Appendix G.

10.6 Recommended mitigation options

Table 10-2 provides a mitigation option evaluation matrix. A rating of 5 implies most desirable for the community while a rating of 1 implies least desirable. Following consideration of the hydraulic, social and environmental impacts of each mitigation option, it is recommended that a combination of options be considered.

The best structural measure (Option 6) involves the construction of a new levee bank around the majority of the town. However there are significant issues with this option that are not drawn out sufficiently by the evaluation matrix – these include the fact that the levee embankment would need to be 2 to 3 metres high to protect from an event the size of the 1990 flood, would have a substantial footprint associated with it that would impact on residence adjacent to the levee, would limit access and visual amenity to the creek and would adversely impact on properties on the eastern bank of the creek. Therefore whilst Option 6 is shown to benefit the majority of area directly affected by flooding it does have significant issues to be considered further by Council.

There are a number of non-structural measures that rate highly including:

- Introduction of a community awareness campaign – This would update residents and appropriate disaster management personnel on the current flood warning system and procedures.
- Augmenting/Automating the flood warning system – in particular automation of the stream gauges at Alpha and Rivington should be considered to provide residents and disaster management personnel with as much time as practical to prepare for inundation due to the rising flood waters. If appropriate other locations further upstream possibly should be also considered if this will lengthen the warning time. The data collected by the automated stream gauges would also assist in the modelling of design events and the setting of flood immunity standards from this data.
- Planning control measures – all new houses should have floor levels above the highest recorded historical flood level and this may well be Council's current requirements. The State Planning Policy SPP 1/03 requires a Defined Flood Event ("DFE") be adopted by Council for planning considerations. When design flood events are able to run through the flood model, this DFE can be selected from these events with an appropriate freeboard allowance. In the interim it is recommended that the highest known flood level be used plus an appropriate freeboard. When the design events are modelled it will also be important to consider the impacts of climate change upon flooding – particularly in relation to increased rainfall.

The raising of houses should also be considered. In the cost estimates carried out it has been assumed that all houses with floor levels below the 1990 flood level can be raised. This may well not be the case due to the construction and/or age of the buildings. If no physical measures are put in place to prevent flow of water through the town then raising of existing impacted houses may be an action that Council wishes to consider further.

Based on the outcomes of this investigation, it is recommended that the above non-structural options and house raising be considered for implementation at Alpha.

Table 10-2 Mitigation Option Evaluation Matrix

Option Number	Description	Hydraulic Benefit		Cost Benefit		Social Benefit		Env. Impact		TOTAL	
		Weight	4	Weight	2	Weight	2	Weight	2		
		Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score	Raw Score	Weighted Score
1	Removal of Central Railway (embankment and structures)	1	4	2	4	2	4	3	6	7	18
2	Removal of Capricorn Highway (embankment and structures)	1	4	2	4	1	2	3	6	7	16
3	Removal of both Central Railway and Capricorn Highway (embankment and structures)	1	4	2	4	1	2	3	6	7	16
4	Replacement of/addition to existing railway culverts to increase waterway area	1	4	2	4	3	6	3	6	9	20
5	Levee construction along Alpha Creek overbank from the Capricorn Highway to the Central Railway (Location A to Location B)	3	12	1	2	3	6	3	6	10	26
6	Levee construction along Alpha Creek overbank from the Capricorn Highway to the Central Railway extended parallel and to the north of the Central Railway (Location A to Location C)	3	12	2	4	3	6	3	6	11	28
7	Excavation of overbank area D of Alpha Creek north of Alpha	1	4	1	2	1	2	1	2	4	10
8	Dedicated floodway between Swinbourne and Moore Streets from Alpha Creek at the Road Bridge extended to the creek – 10m base, side slopes of 1 in 4, depth 2 to 4m	1	4	1	2	2	4	3	6	7	16
9	A combination of the dedicated floodway and levee A to B	3	12	1	2	3	6	2	4	9	24
10	Introduction of creek channel maintenance from the Capricorn Highway bridge to directly north of Neil Street	1	4	1	2	2	4	2	4	6	14
11	Introduction of creek channel maintenance from south of Alpha extending past Alpha Town	1	4	1	2	2	4	2	4	6	14
12	Raising Affected Properties	1	4	3	6	3	6	3	6	10	22

Table 10-2 Mitigation Option Evaluation Matrix

		Hydraulic Benefit		Cost Benefit		Social Benefit		Env. Impact		TOTAL	
12	Automated Flood Warning System/Augmenting System	1	4	3	6	4	8	3	6	11	24
13	Community Awareness Campaign and Training	1	4	5	10	5	10	3	6	14	30
14	Planning Control Measures	1	4	5	10	5	10	3	6	14	30
15	Purchase of Affected Properties	1	4	1	2	5	10	3	6	10	22

Note: Options are rated on a scale 1 to 5, with 1 being lowest benefit or least desirable and 5 being highest benefit or most desirable. The option with the highest score is the most desirable.

11. Economic assessment of recommended physical mitigation option

11.1 Background

The 1990 floods produced record flood heights of 10.26m and widespread property and infrastructure damage over a large area of inland Queensland including the town of Alpha. This major flooding event has been used in the hydraulic modelling for the Alpha Town Flood Mitigation Study and the determination of mitigation options including a suite of recommended options.

At the time of the 1990 floods, Alpha had a population of about 500 people, 150 houses, 16 businesses and a range of community/government services. The 1990 flooding event resulted in flood damage to 123 houses with approximately 70 houses flooded completely. The raising of residential housing in the flood prone area has been recommended as a mitigation option. Flooding damage was recorded to 15 commercial/industrial businesses in the Shakespeare Street /Milton Street and surrounding area. These same businesses have mainly been constructed with heavy building materials (brick, stone and metal) and there is little possibility of them being cost effectively raised or flood proofed in other ways.

The total estimated damage at Alpha attributed to the 1990 flood was estimated to be $1.6 million (in 1990 prices) comprising of direct damage of $1.25 million (ie residential damage of $850,000 and commercial/industrial business damage of $400,000) and indirect damage of $375,000. Government infrastructure and services damage (ie roads, railway, other infrastructure losses, government repairs and restoration work etc) and vehicle damage was excluded from the total estimated damage costs.

In addition to the property and infrastructure loses, there would have been significant adverse road and rail transport operations losses through the temporary disruption to services cut by the flooding of the Western rail line and the Capricorn Highway. These costs have not been included in the total damage estimate.

11.2 Current situation

Currently Alpha has a population of around 370 persons and a housing stock of 500 residences. Alpha has a range of commercial and industrial businesses necessary to service a rural town and surrounding locality. The commercial businesses, including a handimarket, café, bakery, newsagency, hotel/motel, service station, financial services and stock and station agent etc, are primarily located on and around Shakespeare St/Milton St area. Other commercial/industrial activities including livestock and field services businesses, sawmill, caravan park, council depot site are situated in appropriate locations in Alpha.

In addition, Alpha is endowed with community infrastructure and services including the hospital , emergency services (ambulance, fire, police and SES), state school, churches (Catholic, Uniting and Anglican), community centre, golf club and showgrounds.

In terms of 2007 prices and assuming the same level of flood damage, the escalated total damage bill would be $2.5 million comprising direct property damages of $1,917,000 (ie residential flood damage of $1,304,070 and commercial/industrial business damage of $613,680) and other indirect damages of $575,325. Government costs would be over and above this amount.

11.3 Economic impact of housing raising works

A cost benefit analysis model using discounted cash flows has been developed to assess the economic impact of raising houses to flood proof these residences.

The assumptions that have been used to assess the impact of raising houses are detailed in Table 11-1.

Table 11-1 Analysis assumptions

Item	Assumption
Housing raising costs	Taken from Report Appendix G • Number of houses: 80 • Cost per house: $40,000 • Total Cost: $4,480,000 (in 2007 prices)
Construction Period	Assumes that all house raising to be done in one year
Alleviation of flood damage to residential	Estimated flood damage cost to be alleviated by house raising (direct and indirect) is estimated at $1,400,000 (2007 prices) per flooding event comparable to the 1990 event that equates to annual escalated damage cost alleviation of $35,000 over 40 years.
Escalation costs from 1991 to 2007 prices	Consumer Price Index for Brisbane has been used and returns an escalation of 53.4% over the 17 year period.
State and other government costs	These costs relating to residential damages were not included in the original 1991 damage estimates and hence have been excluded in 2007 costs.
Flood event occurrence	Results are based on 1 future flood event occurrence over the next 40 years to the extent of the 1990 floods.
Discount Rate	5% discount rate that is commonly used for social infrastructure projects
Residual Value	It is assumed that the house raising work will have some residual value at the end of the 40 year assessment period. Houses generally have an effective asset life (with proper maintenance) well beyond 40 years. Therefore, a 25% residual value on the house raising costs has been assumed as a benefit at the end of the 40 year assessment period.

On the basis of an average annual estimated direct and indirect residential damage cost of $35,000pa over 40 years, this represents an aggregated present value of $601,000 over the same period. When the present value of $159,000 for the residual value is added, the total present value of benefits is estimated around $760,000.

The resulting benefit cost ratio (BCR), namely the ratio of the present value of costs ($4,480,000) to the present value of benefits ($760,000) is calculated at 0.2.

The results are for one flood event occurrence to the extent of the 1990 flood damage at Alpha. Each subsequent and additional flood event will serve to multiply the BCR of 0.2.

The cost benefit analysis modelling and resulting BCR have been prepared to give some guidance on the indicative economic impacts on implementing the house raising option. Given the need to go out to the market to secure competitive tender prices for the house raising work at Alpha and also the use of escalated 1990 residential flood damage costs to determine average annual damage alleviation benefits, the modelling results are hence heavily qualified and appropriate to the planning phase of this study only.

If State government and local government costs and charges for repairing and restoring flooded housing at Alpha is added to the benefits side of the modelling, then the net benefits and subsequent BCR would be further improved but not to the extent of reaching the breakeven criteria of 1.0.

Finally, BCRs for flood mitigation works generally do not exceed the breakeven level of 1.0 because of the high construction costs of mitigation works relative to the community benefits that are realised. Flood mitigation works including the house raising option are classified as social and/or community infrastructure initiatives and can be justified on the basis of intangible quality of life benefits such as lessening the community disruption and trauma caused by a major flood event. These intangible benefits are not monetised in the cost benefit analysis modelling and are a significant qualitative benefit.

12. Conclusions and recommendations

The Alpha Town Flood Mitigation Study commenced with an extensive data collection phase including compilation of meteorological records, maps, historical flood records, anecdotal accounts, photographs, reports, survey and statistics. This information was collated and used at various stages throughout the project.

A number of consultation activities were undertaken as part of the study. The consultation served a number of purposes including:

- Informing residents of the study aims, progress and outcomes;
- Collection of anecdotal information from witnesses of flood events or damage; and
- Maintaining community awareness of flooding and flood related issues.

The consultation activities included newsletters, public meetings, displays and questionnaires. The consultation process was considered a success, with positive feedback received from residents and valuable information obtained to assist with the technical components of the study.

An URBS hydrologic model was developed for the Alpha Creek catchment upstream of Alpha as this is the model used by the BoM's flood forecasting system. A 2-dimensional MIKE 21 model encompassing the town area was prepared using aerial photogrammetry and field survey provided for the study. The 1990 historical flood event was used as the primary calibration event and the 1997 and 2003 flood events were also modelled to confirm the model calibration.

Flood levels for the historical events were surveyed prior the study and were used to confirm the calibration of the models. Final calibration levels were considered to be within an acceptable range from the recorded flood levels. Residents who had witnessed these events confirmed that the modelled flood behaviour generally represented conditions during the event.

Following calibration, an attempt to model design flood events was carried out but was hindered by the lack of a complete data set from the stream gauge in Alpha. Only large events were recorded by the manually read gauge and thus a complete record of events was not available for flood frequency analysis purposes. This combined with the varied loss parameters derived for the large and smaller historical flood events meant that it was not possible to derive and confirm appropriate design storm and flood levels for Alpha at this time.

Hazard maps were produced for the 1990 historical flood event to enable the disaster response organisations to better assess evacuation routes and safe areas – though at the peak of the 1990 flood event the majority of the town is within the extreme hazard zone.

An assessment was also made as to the effects of the road and rail embankments through Alpha, with respect to flooding in the town. A comparison was made between the base case, with no road or rail embankments, and the cases with the road and rail in isolation and combined. It was concluded that both embankments had minor impacts when an event of the magnitude of the 1990 event occurred. Under smaller events the impact of these structures, whilst localised, would be more significant.

Following the assessment of the existing floodplain situation a number of structural and non-structural mitigation options were developed. The structural options were modelled in MIKE 21 to assess the impacts on flooding within the town. Options considered included:

- Upgrading crossing structures under the rail line;
- Introduction of a new levee around the town;
- A dedicated floodway through town;
- Creek channel maintenance or desiltation; and
- Various combinations of the above.

It was concluded that the most significant reduction in flood levels within the town would be achieved with the construction of levees. However there are significant issues associated with consideration of the levee option including impacts on landholders outside the levee, potential overtopping of the levee, impacts on access to the creek and visual amenity as well as the high cost and large size of the levee bank.

Another structural mitigation option was to raise the flood prone houses above the 1990 event flood level. This could not be modelled in MIKE 21 and was therefore considered in terms of benefit and cost only. This was considered to an effective option but slab-on-ground structures would not be suitable for raising.

Non-structural options were also considered, including:

- Automated flood warning system;
- Augmenting the existing flood warning system;
- Community awareness campaign; and
- Town planning considerations.

Of these options, the community awareness campaign is a low cost option that would result in residents becoming familiar with procedures for flood related activities including evacuation plans. A campaign should also involve training of disaster management personnel.

All of the options have been evaluated in terms of hydraulic impact, cost, environmental impact, social benefit and economic impact. An evaluation matrix was prepared to assist in the selection of preferred options. The Evaluation Matrix assisted in confirming that the following options should be considered for implementation at Alpha:

- Community awareness campaign and training;
- Raising of houses;
- Augmentation/Automation of flood warning system; and/or
- Planning control measures.

13. Explanatory statement

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14. References

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Figures – refer Volume 2

Figures

Appendix A

Community Consultation Newsletters

Appendix B

Community Consultation Survey Forms

Appendix C

Regional Ecosystem Map

Appendix D

Scott and Furphy Report

Appendix E

Bureau of Meteorology Flood Warning Network Map

Appendix F

Mitigation Measures Cost Estimates

Appendix G

Social Impact Summary

Appendix G

Social Impact Summary

Option	Summary of Social Impact	Stakeholders Affected	Positive Benefits	Potential Risks
M1	No significant benefits to 1990 flood levels	All members of the community	Increase in positive public perception that "something" is being done about local flooding issues. Railway generally considered to impede drainage of flood waters.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Option considered by the community to be impractical and not the real source of the problem. Necessity to undertake additional flood mitigation works locally which would include additional local resources.
		Queensland Rail	Nil identified	Cost to QR and consequent impacts on local use of railway services – both short and long term. Environmental impacts of alternatives to existing rail infrastructure. Disruption to local rail transport services.
M2	No significant benefits to 1990 flood levels	All members of the community	Slight increase in positive public perception that "something" is being done about local flooding issues.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Option considered by the community to be impractical and not the real source of the problem. Necessity to undertake additional flood mitigation works locally which would include additional local resources.
		Department of Main Roads	Nil identified	Cost to DMR and consequent impacts on local use of road services – both short and long term. Environmental impacts of alternatives to existing road infrastructure. Disruption to local road transport services.

Option	Summary of Social Impact	Stakeholders Affected	Positive Benefits	Potential Risks
M3	No significant benefits to 1990 flood levels	All members of the community	Increase in positive public perception that "something" is being done about local flooding issues.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Option considered by the community to be impractical and not the real source of the problem. Necessity to undertake additional flood mitigation works locally which would include additional local resources.
		Department of Main Roads, Queensland Rail	Nil identified	Cost to DMR and QR. Disruption to road and rail transport services.
M4	No significant benefits to 1990 flood levels	All members of the community	Increase in positive public perception that "something" is being done about local flooding issues. Railway generally considered to impede drainage of flood waters.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business.
		Queensland Rail	Nil identified	Cost to QR. Disruption to local rail transport services.
M5	Moderate benefit to 1990 flood levels and evacuation time on the west bank	All members of the community	Increase in positive public perception that "something" is being done about local flooding issues. Reduction in peak water levels. Delay in inundation allowing for evacuation of property and people.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Increased flooding on east bank, probably preventing future development in this area. Necessity to undertake additional flood mitigation works locally which would include additional local resources. Cost to local council.

Option	Summary of Social Impact	Stakeholders Affected	Positive Benefits	Potential Risks
M6	Significant benefit to 1990 flood levels and evacuation time on the west bank	All members of the community	Increase in positive public perception that "something" is being done about local flooding issues. Protection to at least a 1990 magnitude event.	Increased flooding on east bank, probably preventing future development in this area. Cost to local council. Potentially creates a sense of 'flood imminence" and uneasiness for residents. May lead to devaluation of property. Breaching failure would be catastrophic.
M7	No significant benefits to 1990 flood levels	All members of the community	Slight increase in positive public perception that "something" is being done about local flooding issues.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Cost to local council.
M8	No significant benefits to 1990 flood levels	All members of the community	Slight increase in positive public perception that "something" is being done about local flooding issues.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Cost to local council. Potential negative effect on evacuation routes. Potential public safety if concentration of flow increases velocities
M9	Moderate benefit to 1990 flood levels and evacuation time on the west bank	All members of the community	Increase in positive public perception that "something" is being done about local flooding issues. Reduction in peak water levels. Delay in inundation allowing for evacuation of property and people.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Increased flooding on east bank, probably preventing future development in this area. Necessity to undertake additional flood mitigation works locally which would include additional local resources. Cost to local council.

Option	Summary of Social Impact	Stakeholders Affected	Positive Benefits	Potential Risks
M10	No significant benefits to 1990 flood levels	All members of the community	Significant increase in positive public perception that "something" is being done about local flooding issues.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Cost to local council. Necessity to undertake additional flood mitigation works locally which would include additional local resources.
M11	No significant benefits to 1990 flood levels	All members of the community	Significant increase in positive public perception that "something" is being done about local flooding issues.	Continued impacts associated with flooding, such as safety, community health, isolation, access to medical services, damage to property and continued operation of local business. Cost to local council. Necessity to undertake additional flood mitigation works locally which would include additional local resources.